# ENDURO K·A·2 STEEL

AN EPOCHAL INTRODUCTION



OF INTERNATIONAL
» IMPORTANCE «

# ENDURO K·A·2 STEEL

(Entirely Distinct from Present Stainless Alloys)

IS NOW MADE AVAILABLE
TO AMERICAN INDUSTRY
THROUGH AMERICAN
· · · ENTERPRISE · · ·

*Produced under Krupp-Nirosta Patents and under the Supervisory direction of Prof. Doctor Benno Strauss, Director of Research, Fried Krupp A.G. Germany*

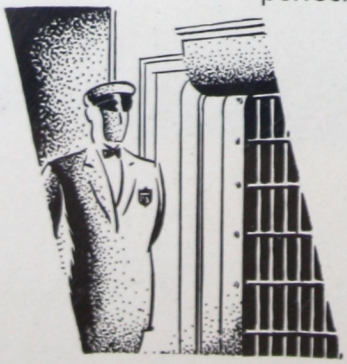
**ENDURO NIROSTA STEEL**

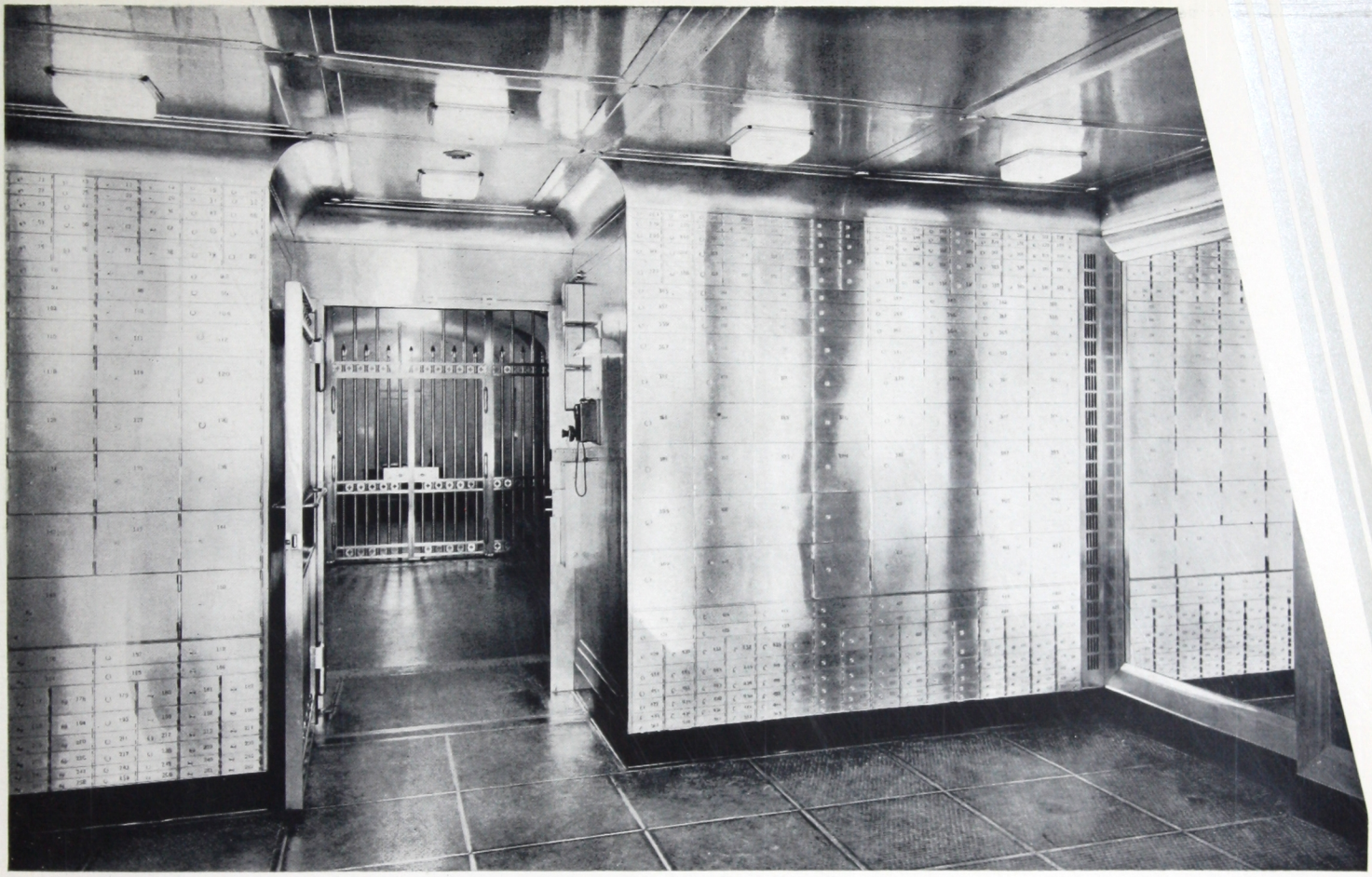
CENTRAL ALLOY STEEL CORP. · MASSILLON, OHIO
LUDLUM STEEL COMPANY · · WATERVLIET, N.Y.
THE BABCOCK & WILCOX TUBE CO. · NEW YORK, N.Y.

# A NEW METAL
## FOR MODERN DAY USES

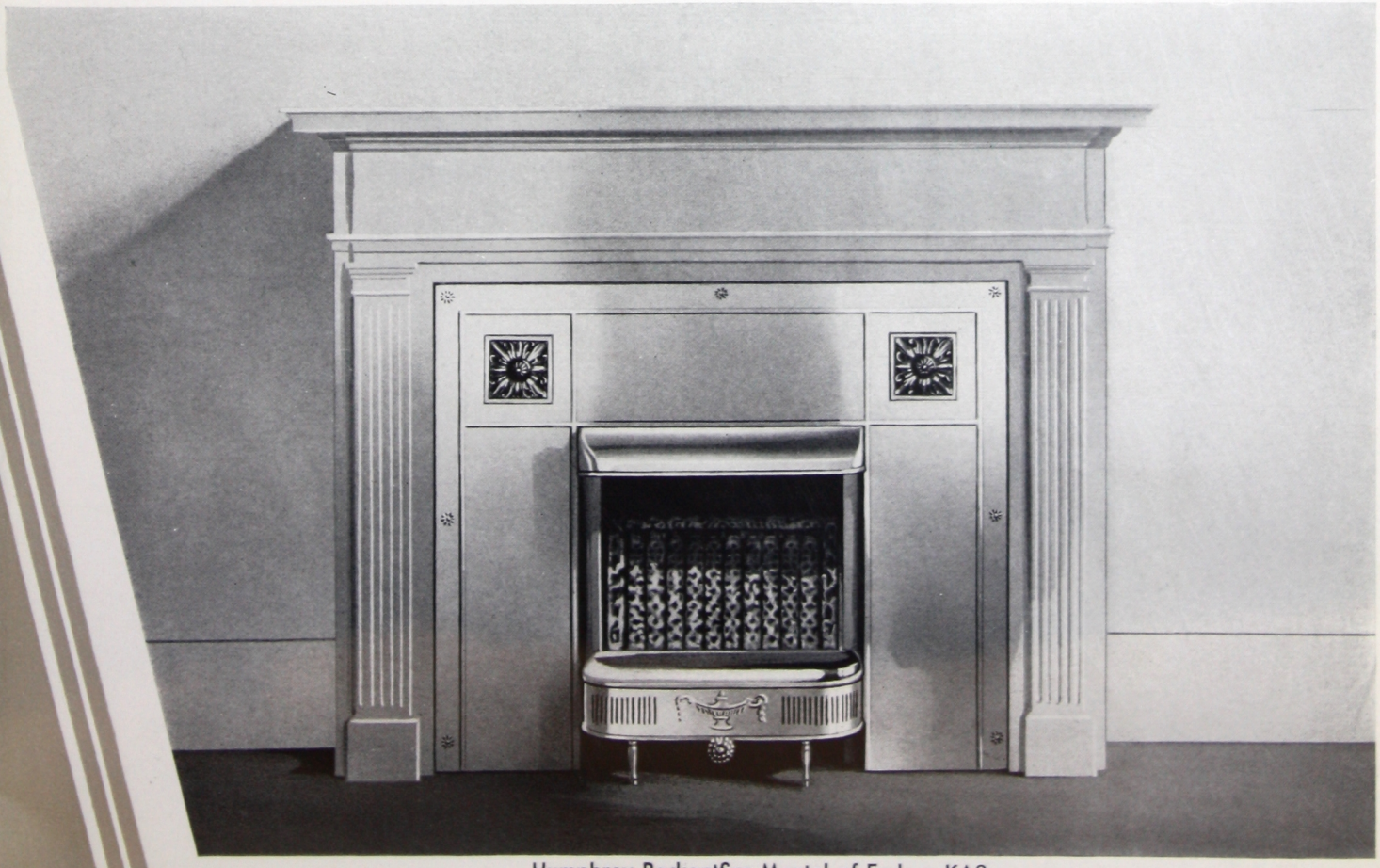
Ancient alchemists spent their lives in futile attempts to transmute baser metals into gold. Metallurgical engineers, alchemists of today, direct their efforts along more practical lines, yet they have reached some of the goals for which their predecessors strove in vain. ¶ The alloying of metals has become a science, the application of which grows ever wider. Enduro KA2, an alloy of chromium, nickel and iron, partakes of the nature of a noble metal and is perhaps the highest expression of the metallurgist's art. When polished it is proof against water, atmospheric attack, dilute solutions and even acids at high temperatures and at high pressures. It takes, and holds, a mirror finish which is untarnishable under all atmospheric conditions. ¶ Stronger than carbon steel, it is easily workable. It can be deep drawn, wire drawn, spun, machined and welded. Such a combination of unusual properties might presuppose a price proportionately high. Enduro KA2 costs less than many materials in common use. It is in truth a new metal for modern day requirements.

IN SCORES of applications, Enduro KA2 is used for its striking appearance alone. The Royal Bank of Canada vault at the right, with safe-deposit boxes and ceiling of Enduro, indicates the effect that may be obtained with this material. ¶ The Humphrey Radiant-Fire mantel is another effective application. Its possibilities for decorative treatment in lighting fixtures and fittings of all sorts for homes and buildings are almost unlimited. Plated materials have no appeal in comparison with a metal whose finish can not wear off because it is the same all the way through. ¶ Household appliances of every kind may now have fittings with a gleaming brightness that will never become dull. The automobile of the near future will achieve a new beauty with this material of permanent lustre. It is now being used in hood hinges, body trim, lamp rims, wire wheels, bumpers, radiator and gas tank caps and other parts where good appearance and corrosion resistance are essential. ¶ And wherever equipment must always be spotlessly clean, nothing will provide a greater degree of cleanliness than a metal which is unaffected by any of the solutions with which it may come in contact. Operating tables, sterilizers and much of the furniture and clinical apparatus of the modern hospital will approach the sanitary perfection for which hospitals strive, when made of Enduro KA2.





Safe Deposit Vault, Royal Bank of Canada, Montreal



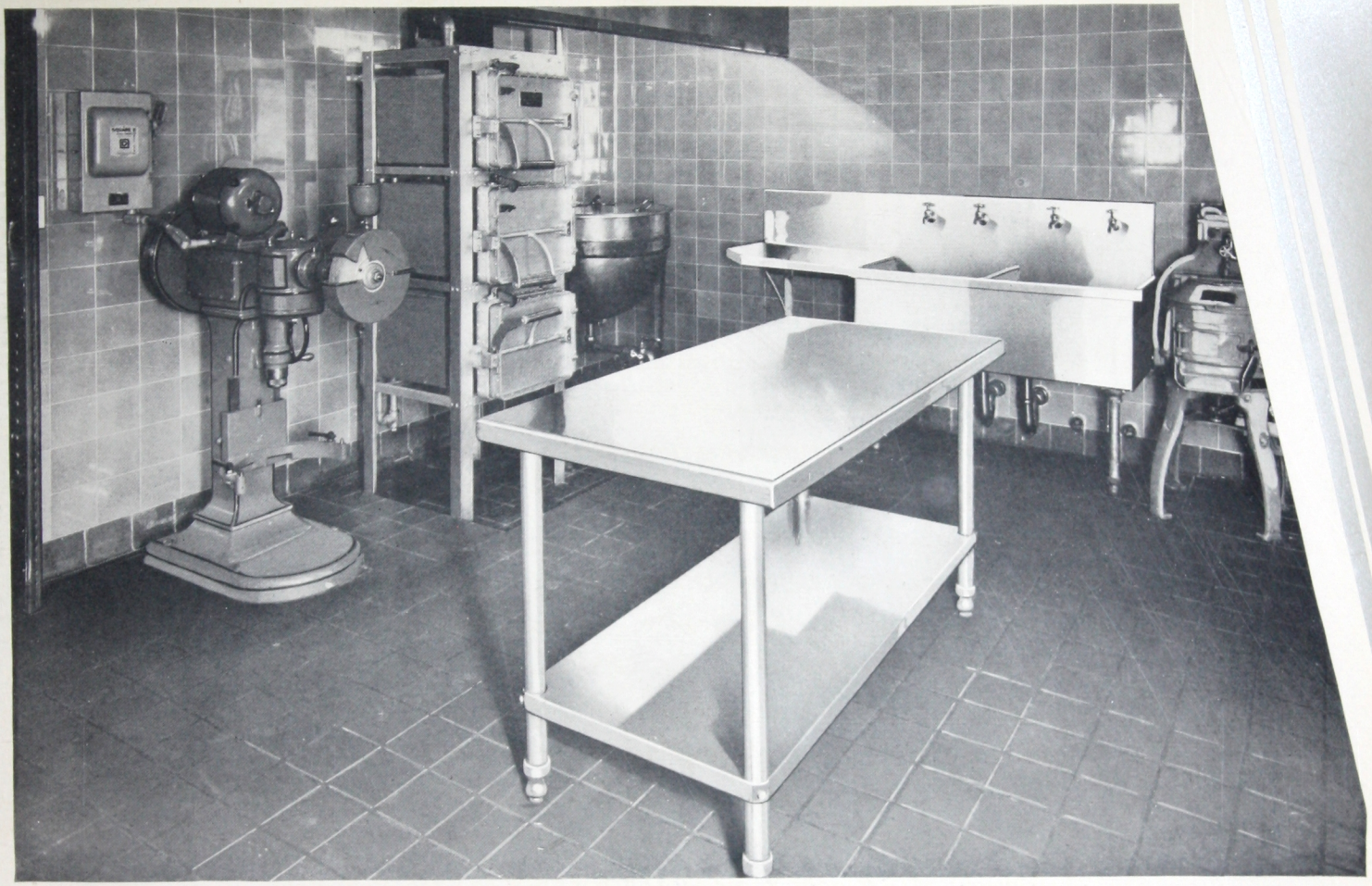
Humphrey Radiantfire Mantel of Enduro KA2

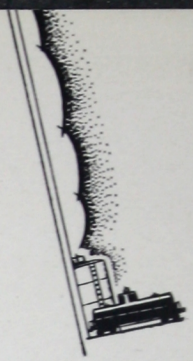
STAINLESS STEELS and irons are not unknown to the American public. Originally employed in the manufacture of cutlery, their remarkable properties have led to a wide development in recent years. Few industries that have not shown the imprint of stainless alloys in some manner. ¶ The straight iron-chromium alloys, however, were not without shortcomings. Their tough, uncompromising nature led to fabrication difficulties. They showed a tendency to become brittle in high temperature applications. Welds were not ductile. The need for a still better material became apparent. ¶ Such a material was developed in Germany. Dr. Benno Strauss, Director of Research of the Krupp Works, discovered that with the addition of a considerable proportion of nickel to the stainless analysis, special processes of heat treatment during manufacture resulted in a metal of greatly superior properties. Its corrosion resistance was increased to the point of complete immunity from the attack of many hitherto active materials. ¶ Resistance to scaling at high temperatures was increased and embrittlement after long service at elevated temperatures was overcome. The heat treating process gave the new material approximately the ductility of copper. ¶ America, with its high standard of living and great industrial structure, was the natural field for such a metal. The Krupp Nirosta Co. has licensed the manufacturers who sponsor this book to produce Enduro KA2 in the United States under the supervisory direction and with the complete cooperation of the great Krupp research staff.

German tableware of Enduro KA2

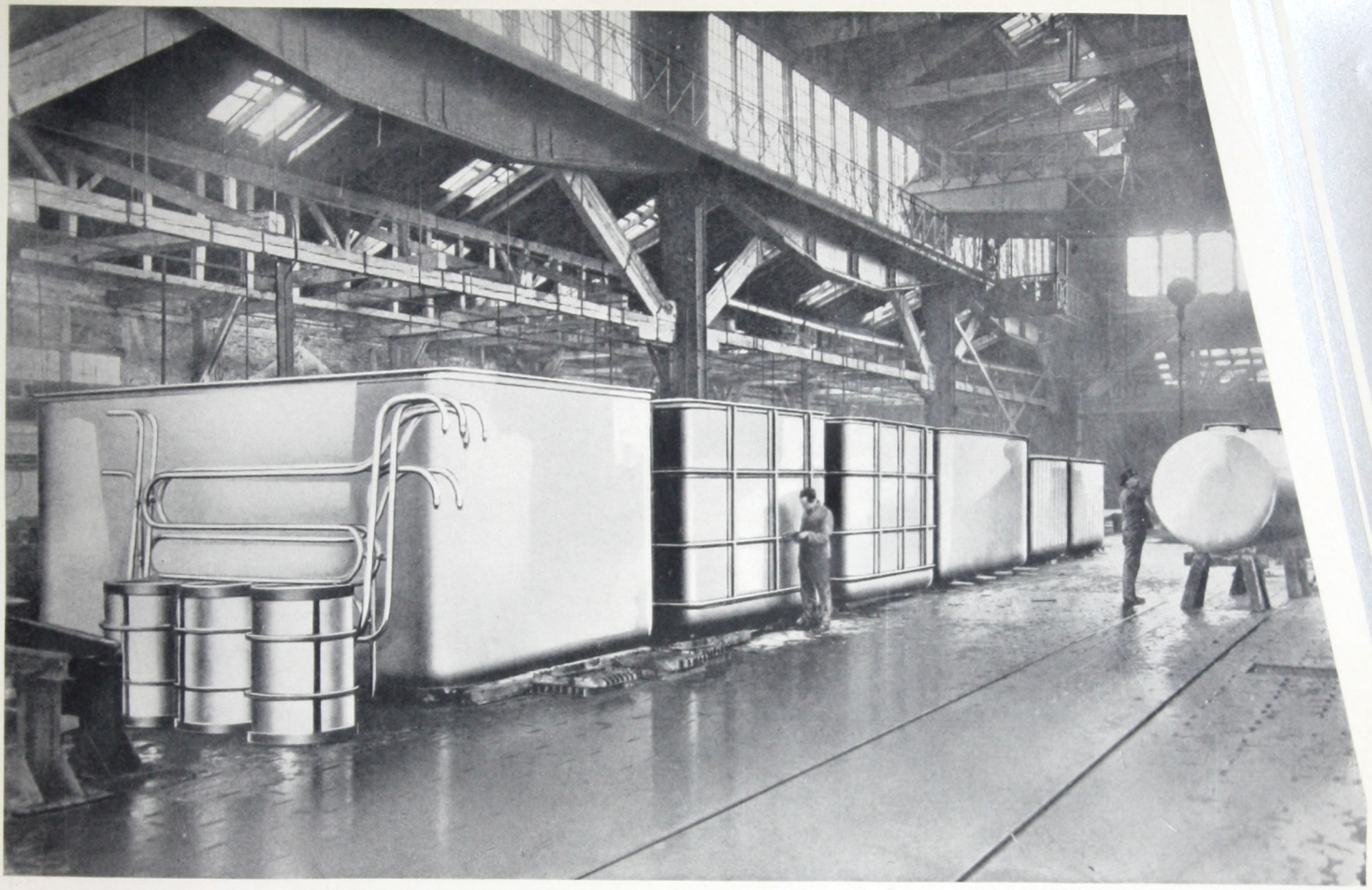
Cooking utensils of Enduro KA2

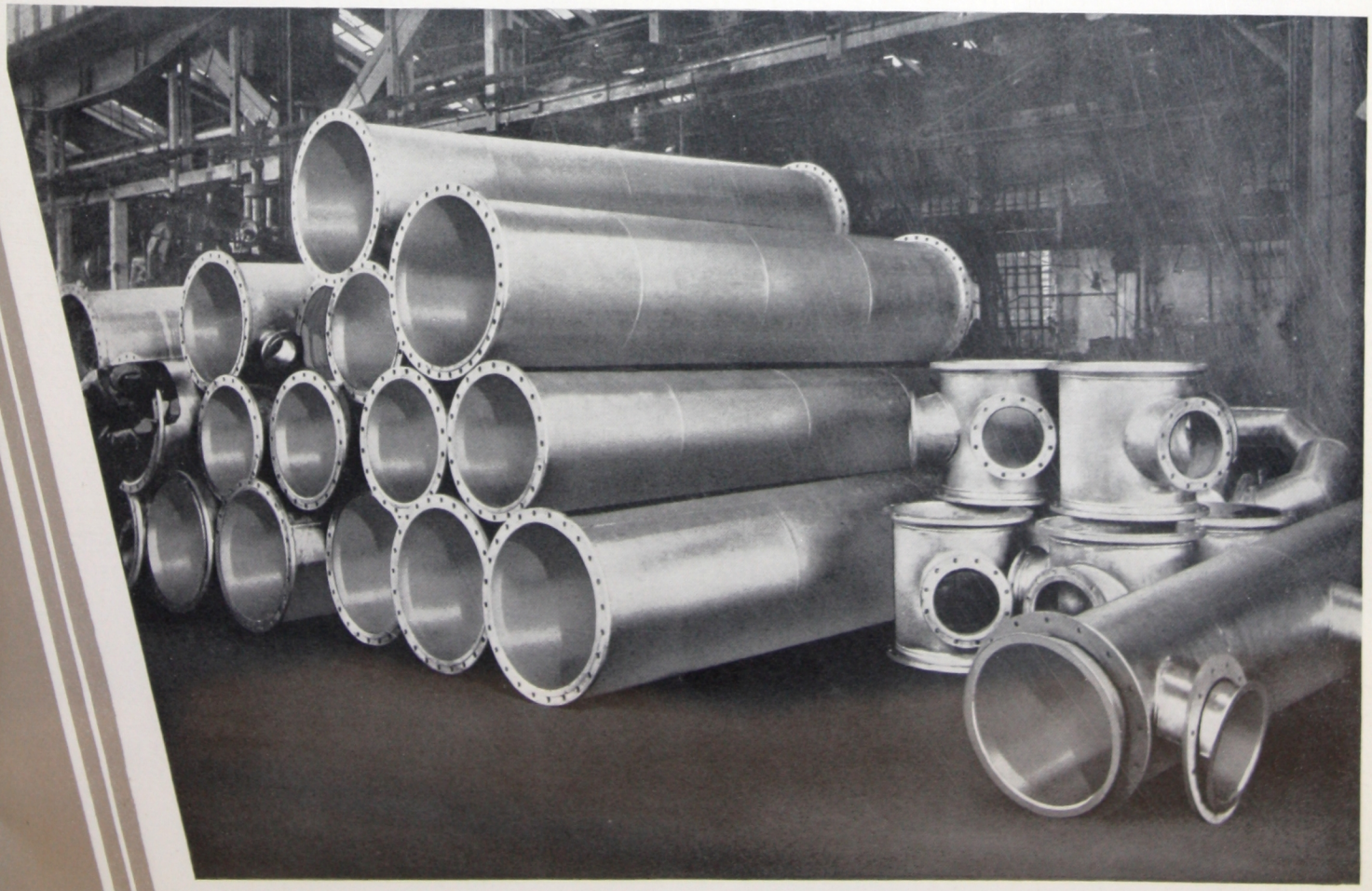
FOOD and its preparation fall naturally within the special field of Enduro KA2. Meat packers and vegetable canneries, fisheries and fruit growers all are confronted with the problem of securing equipment which is not attacked by any of the organic acids at any temperature. Durability is an important factor. Absolute cleanliness, without the drudgery and expense of scrubbing, scraping, scouring and polishing, at last becomes a reality. ¶ Lemons will not stain Enduro KA2. It withstands hot vinegar. Tomatoes and rhubarb can be cooked in Enduro utensils without attack of any kind. Careful chemical analysis of foods cooked in nearly all other types of metallic utensils shows certain proportions of the metals themselves. Foods cooked in Enduro contain not the slightest trace of metallic inclusions. ¶ Designers of modern kitchens and cooking equipment have been quick to adopt Enduro KA2. At the right are two views in the Marcus Ward Home for the Aged of which John Russell Pope was the architect. All cooking equipment was planned by P. C. Quintard, Kitchen Design Consultant of New York City, who is using Enduro liberally in his work. ¶ In cafeterias and restaurants where the handling of food comes under the direct observation of patrons, Enduro KA2 finds immediate acceptance for counter-tops and sides, steam tables and fittings, range hoods and vents and many other applications. Its original brightness is permanent; it is not easily scratched; it cannot be stained by foods or discolored by heat. The preservation, preparation and serving of food is a tremendous industry yet there is no branch of it that will not profit by the use of Enduro KA2.

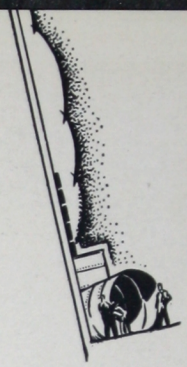




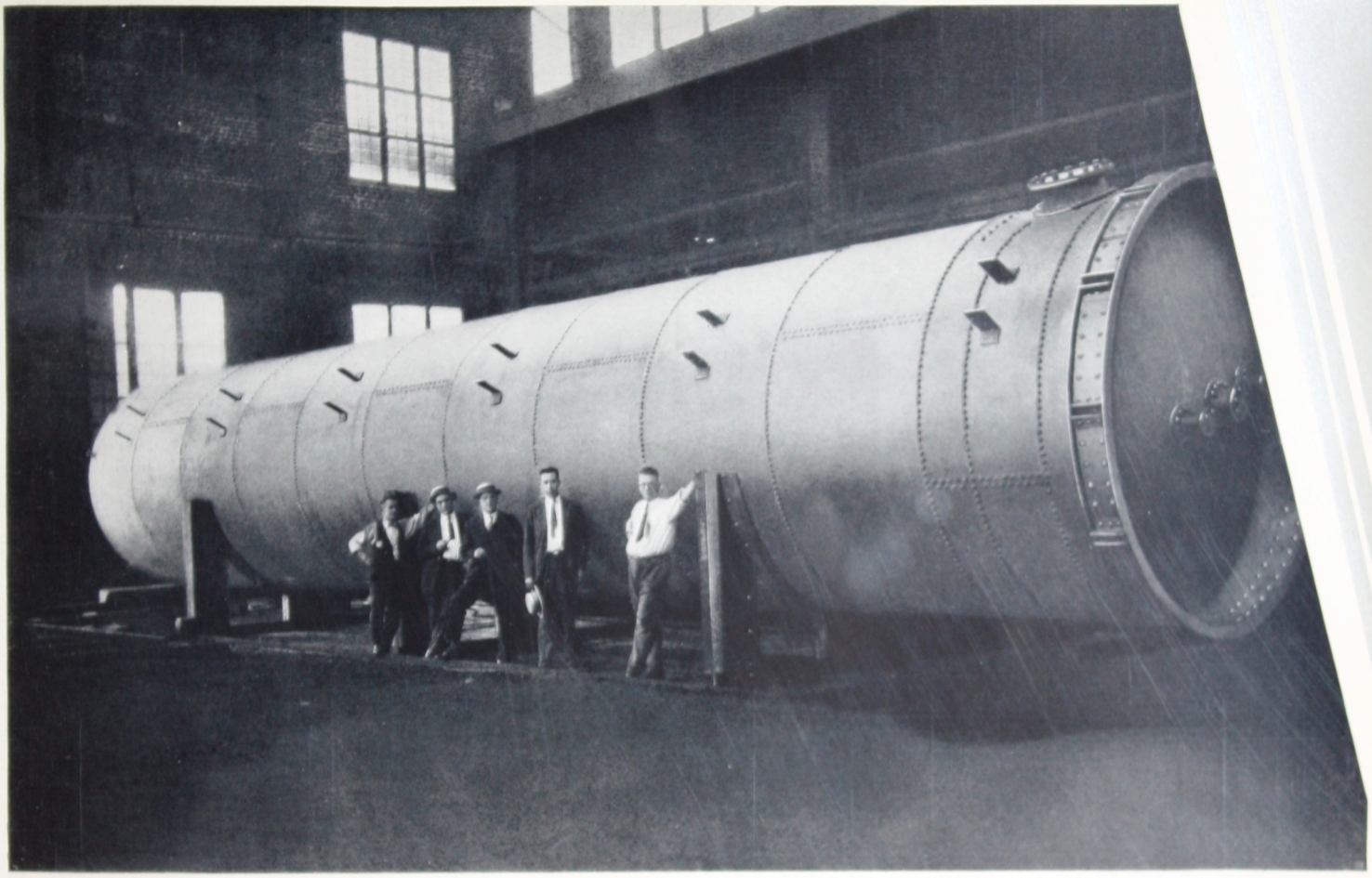
THE PROCESS industries are finding almost countless applications for Enduro KA2. Its high resistance to most acids and chemicals (amounting in many cases to complete immunity from attack) has solved many troublesome problems of equipment design. ¶ Enduro KA2 is impervious to nitric acid in any concentration. It has high resistance to sulphur and sulphur compounds and to many other chemicals and reagents used in the process industries. Metals are corrosion resisting in different degrees, no one metal being immune to all attacking agents. Enduro KA2 is unique in that it is resistant to a wider range of materials than any other corrosion-resisting alloy. ¶ Due to the relative ease with which it may be fabricated, Enduro KA2 is extensively employed in the manufacture of autoclaves, digesters, stills, condensers, tanks, tank cars, acid shipping drums, heat exchangers, evaporators, pipe lines and other chemical plant equipment. ¶ The large tanks and vats shown at the right present no fabrication difficulties when Enduro KA2 is used. Its excellent welding properties are exemplified by the ducts and fittings shown below.

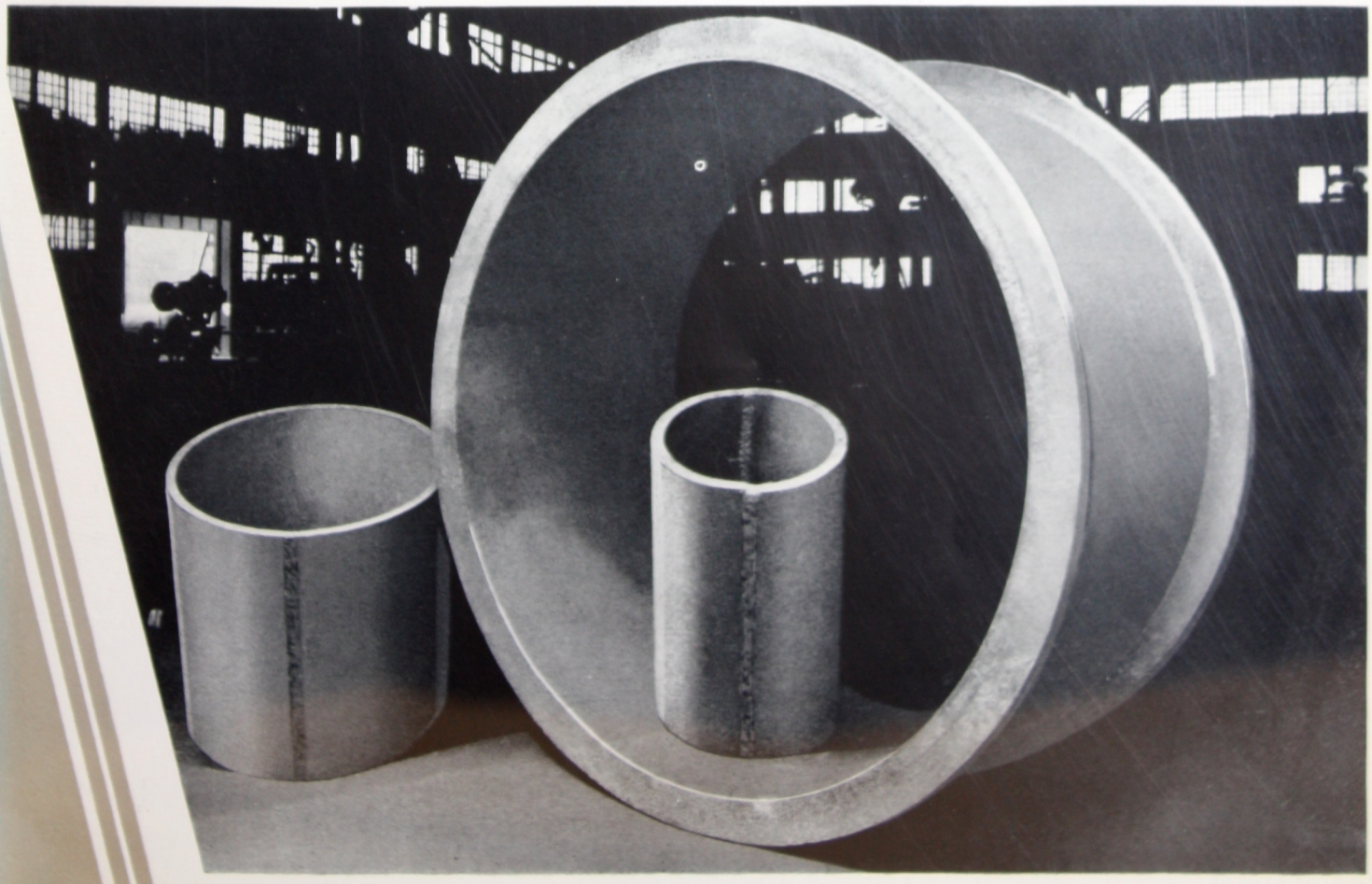


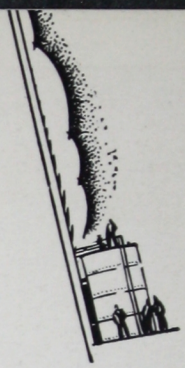




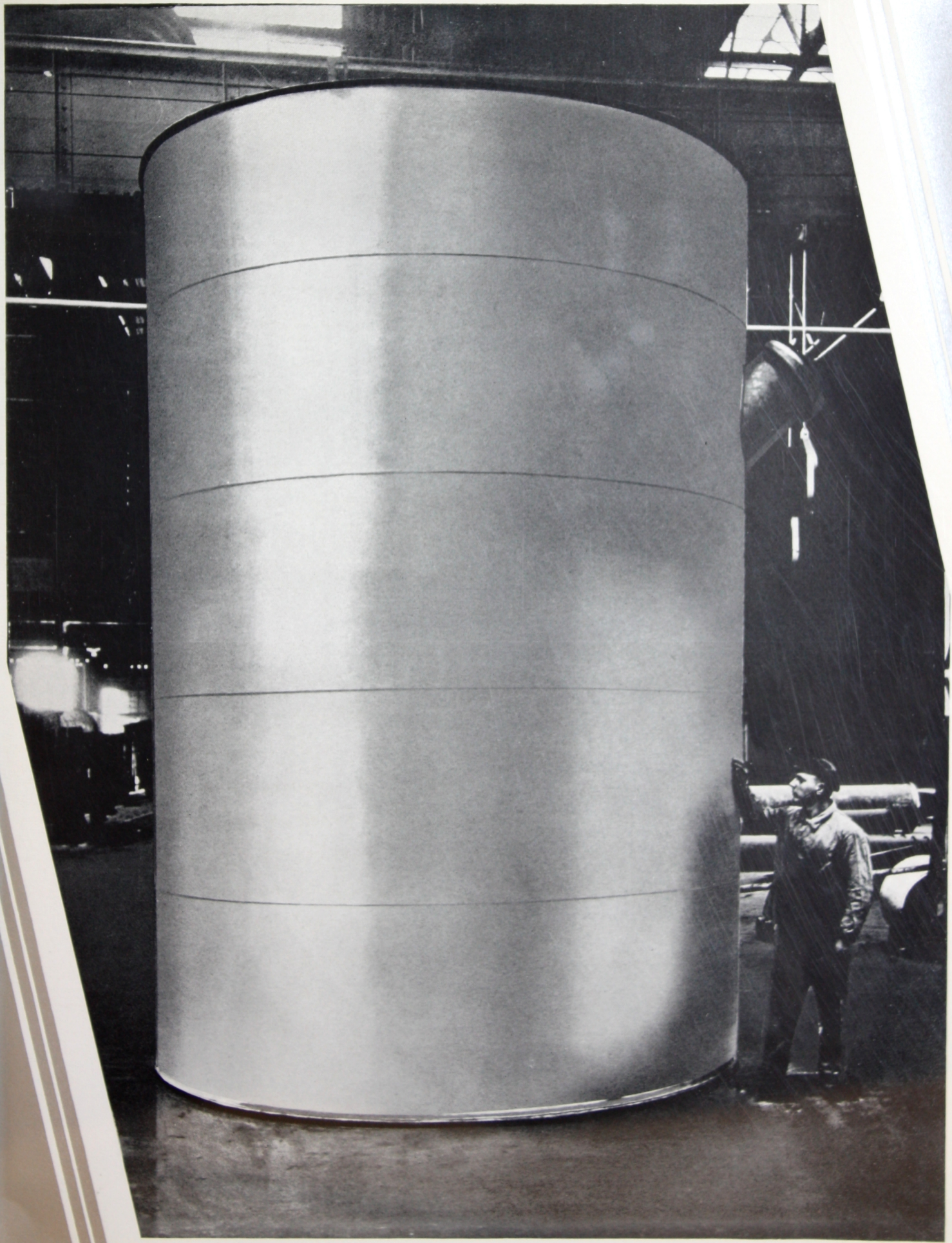
IN BUILDING large apparatus for chemical plant or other uses, Enduro KA2 overcomes many of the production difficulties accompanying fabrication of the straight iron-chromium alloys. The Krupp method of processing makes KA2 much more ductile and easily worked. Large size flanged and dished heads can be formed without difficulty. ¶ Riveting presents no problems, as the riveted nitric acid tower at the right will testify. Enduro KA2 does not harden on rapid cooling nor develop coarse structure on heating. The accurate temperature control required for straight iron-chromium rivets therefore is not necessary. Rivets may be driven at high temperatures or cold, with equal success, the rivet remaining tough and thoroughly dependable. ¶ Tough, ductile welds are obtained with Enduro KA2, due to the fact that it has no capacity for hardening, except by cold-working. At the right are shown welded cylinders of this material. Welding may be accomplished by either the arc or acetylene process, using specially prepared welding rods. Enduro KA2 may also be spot or resistance welded, but cannot be forge- or hammer-welded. These welds do not develop the coarse, crystalline structure characteristic of the straight chromium-iron alloys, but remain tough and ductile. Numerous analyses show that there is little change in the composition of the metal deposited in the weld.





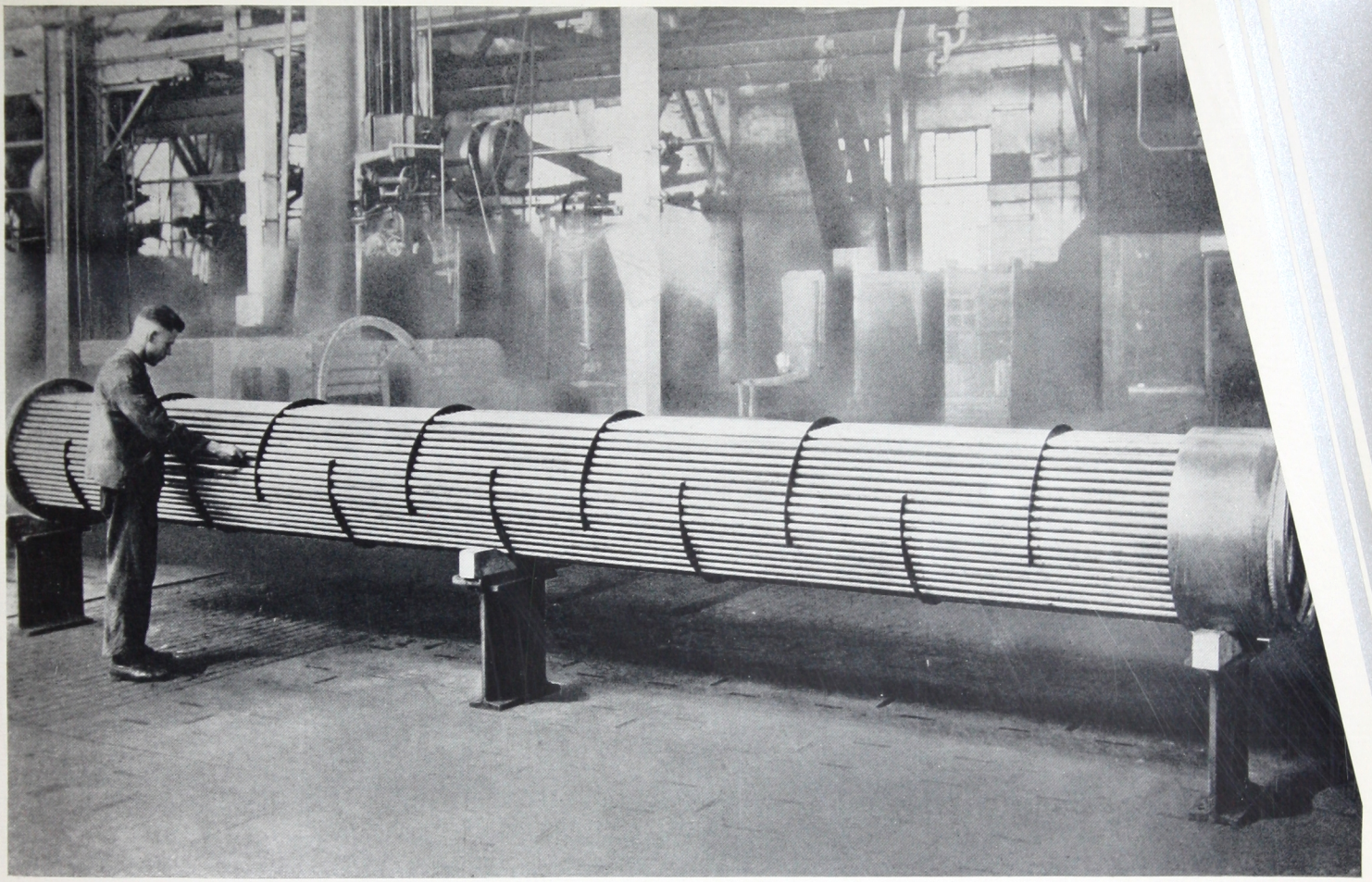


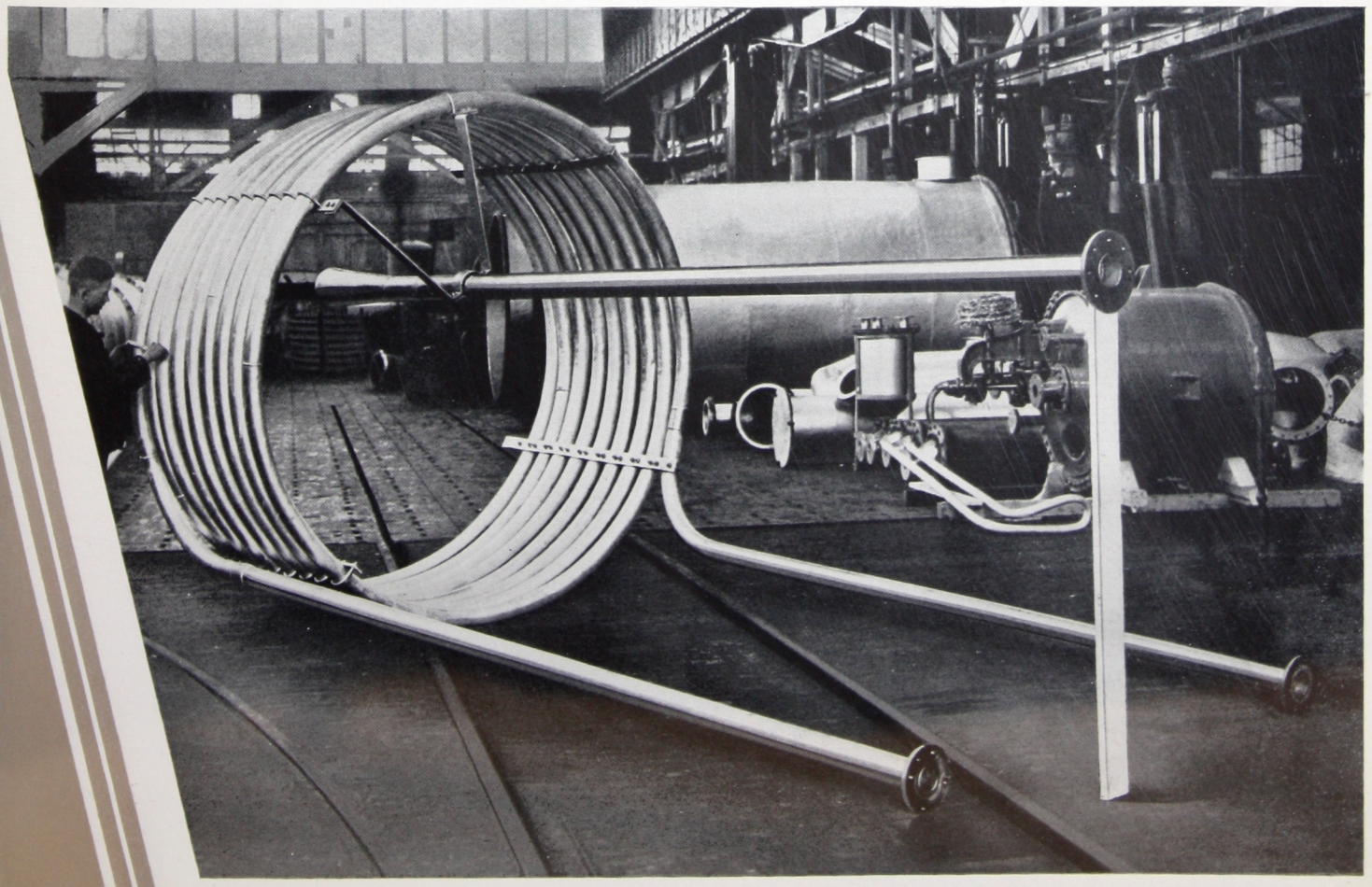
ONE of the major difficulties experienced in the rapidly expanding chemical industries is the selection of materials for apparatus used in the manufacture of corrosive products. No process of chemical manufacture can be considered properly established until a material is found which will permit the process to be carried out on a large scale. Enduro KA2, being resistant to a wider range of materials than any other alloy, naturally has been received with considerable enthusiasm. ¶ The picture at the right shows the outside tank of an absorption tower, built of Enduro KA2 in the Krupp Works at Essen, Germany. The wide European application of this alloy will be duplicated by the chemical industry of this country, for it meets the three important requirements for this type of service—corrosion resistance; high strength with ready workability; availability in all required shapes and forms. ¶ This latter requirement is important in order to avoid electrolytic action, permitting all parts of a given piece of equipment to be constructed of the same material. With KA2, whether the fabrication requires welded or riveted joints, no difficulties are encountered. The availability of plates of any size, as well as sheets, bars, tubes, wire, rivets, bolts, screws, castings and all other construction elements, greatly simplifies the problem of the equipment designer.



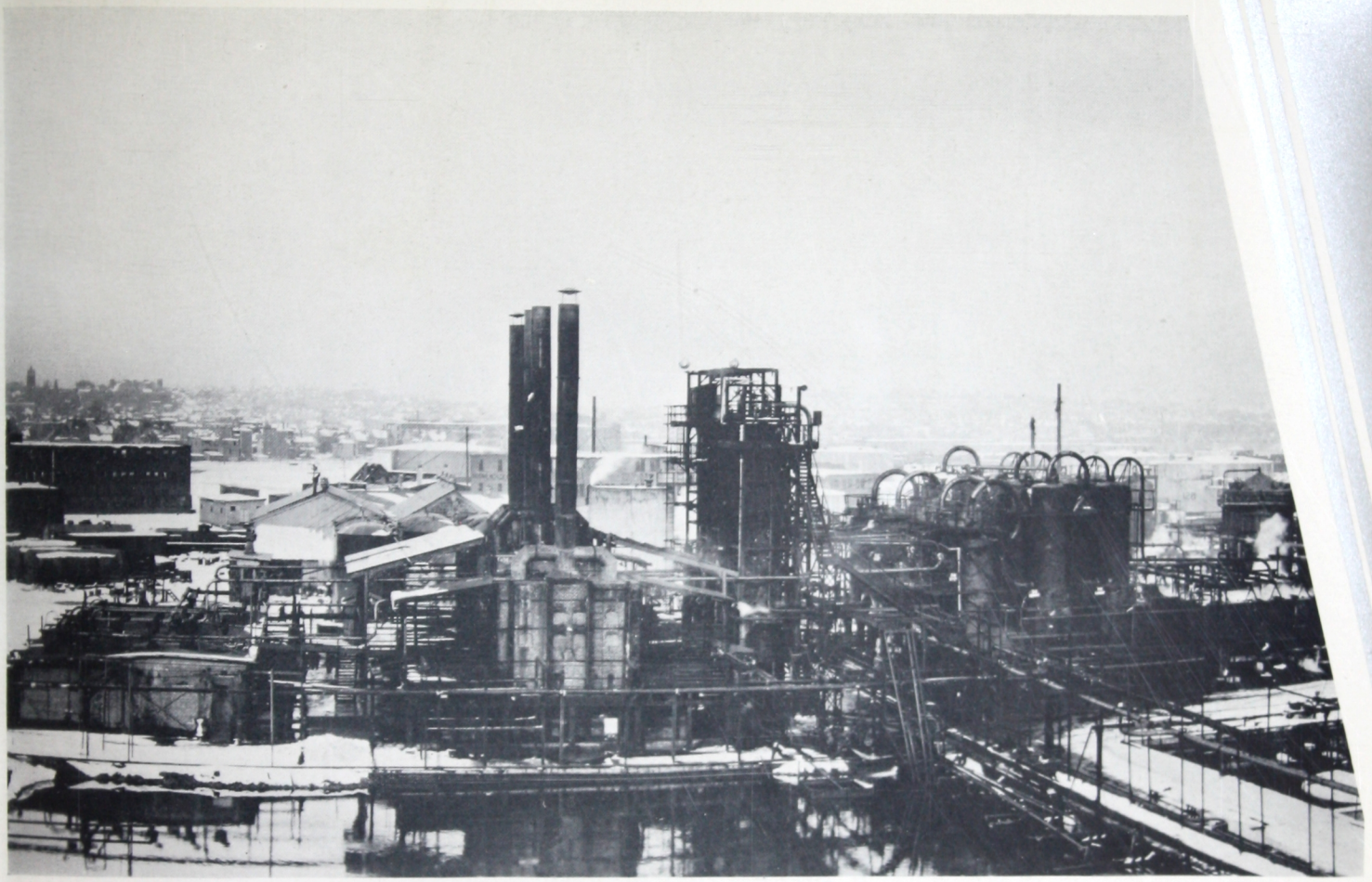
SEAMLESS tubing and pipe of Enduro KA2 are finding an extensive and rapidly increasing use in the various industries where agents corrosive to ordinary ferrous materials must be handled, either as raw or process material, finished product or by-product. Among these industries are: — Canning and Preserving, Dyes, Chemical Plants, Laundries, Dairies and Dairy Machinery, Paper Making and Machinery, Drugs, Powder and Explosives. Not only is Enduro KA2 highly resistant to the corrosive action of agents handled by these and numerous other industries, but the fact that tubes and pipe of this material can be bent, threaded, flanged or otherwise formed with the same ease as ordinary steel, greatly facilitates the work of installation. The great strength and toughness is in marked contrast to the fragility of special non-corrosive materials hitherto used, such as glass, stoneware and high-silicon cast iron, which moreover, cannot be worked or formed to fit.

¶ Should high temperature be combined with corrosive attack, as is often the case, the superiority of Enduro KA2 to other materials becomes even more apparent. ¶ Alert designers of equipment for many industries are familiarizing themselves with the remarkable physical and chemical properties of this material.



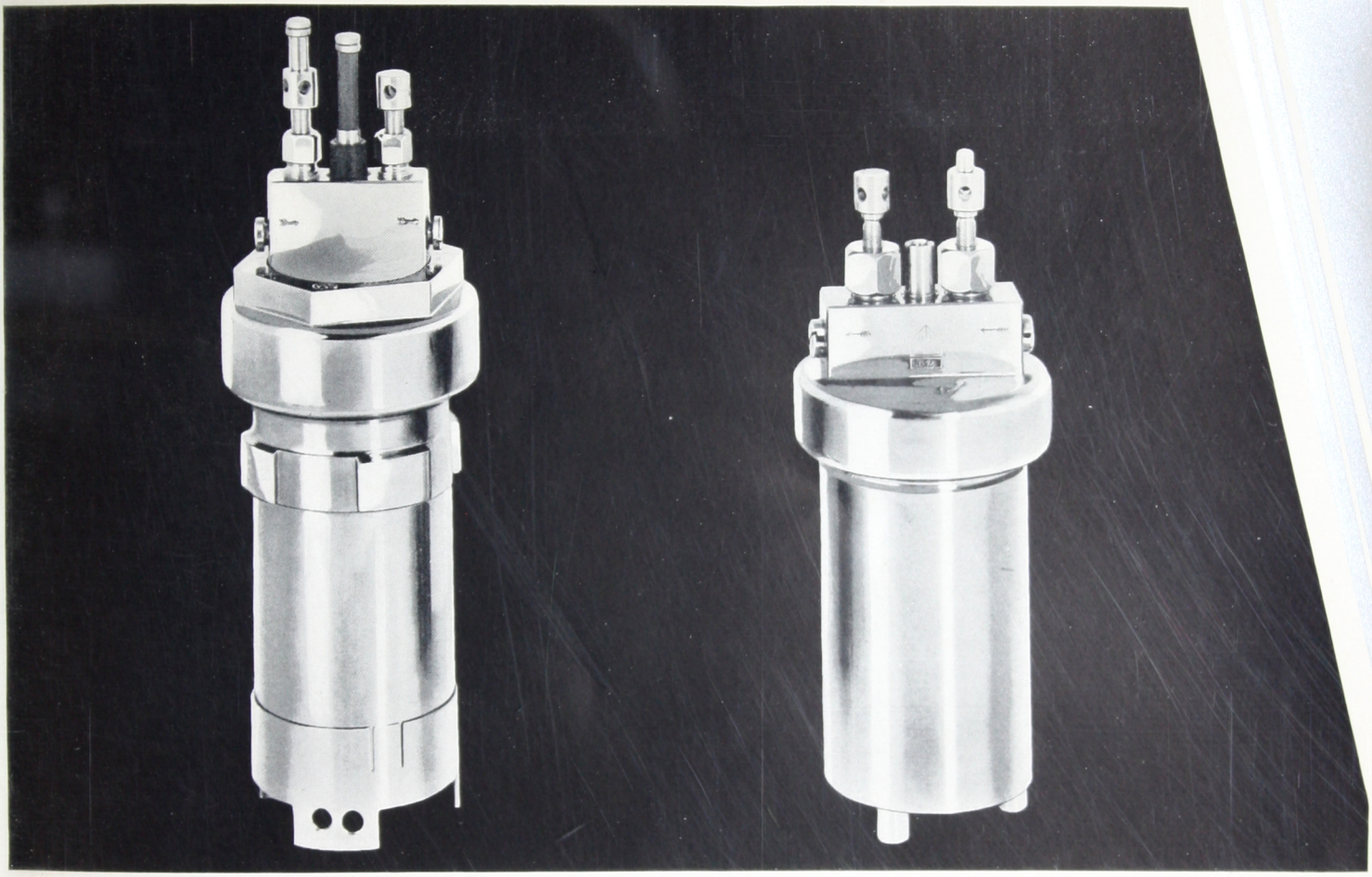


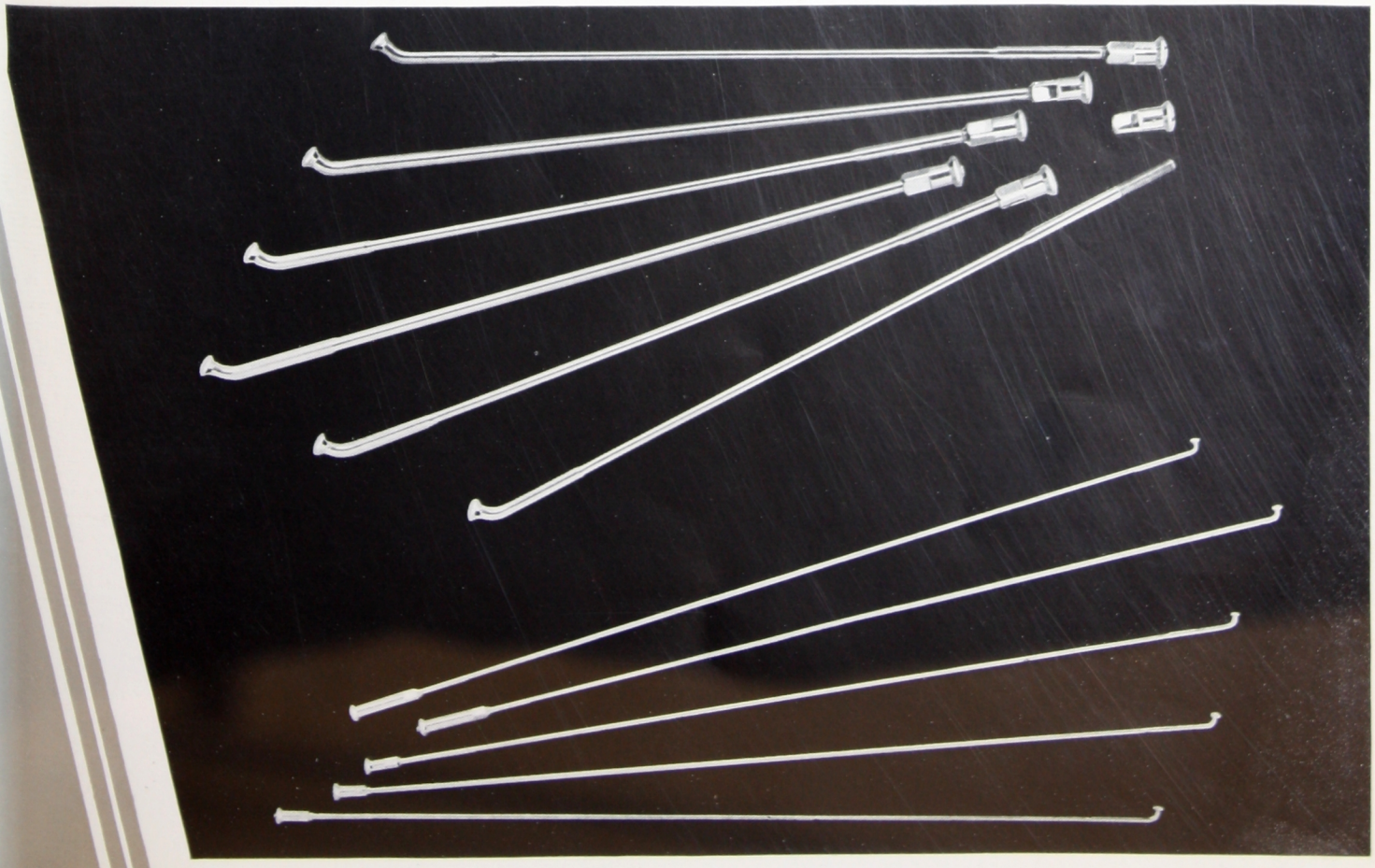
THE INTEREST of the oil refining industry, and the well-directed efforts of its laboratories in seeking out and testing improved materials have enabled this industry to pass rapidly through the experimental stage in the use of Enduro KA2. An outstanding use is in the tubes for high pressure cracking stills. Here tubes of other materials fail through oxidation or weakening at high temperatures, often hastened by the action of corrosive agents in the oil. Costly shut-downs and frequent replacements are necessitated. Seamless tubes of Enduro KA2 have, by actual experience, so far overcome these conditions that they have already been adopted by many of the most prominent refining corporations. Their high resistance to oxidation, their great strength at high temperatures (four times that of carbon steel at 1000° F.) and their comparative immunity to corrosive attack give a life many times that of the best grade of ordinary steel tube. ¶ Similar economies are being effected by the use of this material in other refinery installations where heat and corrosion form a problem. The life of heat exchangers, condensers and other apparatus is being increased many times and shut-downs and replacements avoided, by the use of Enduro KA2



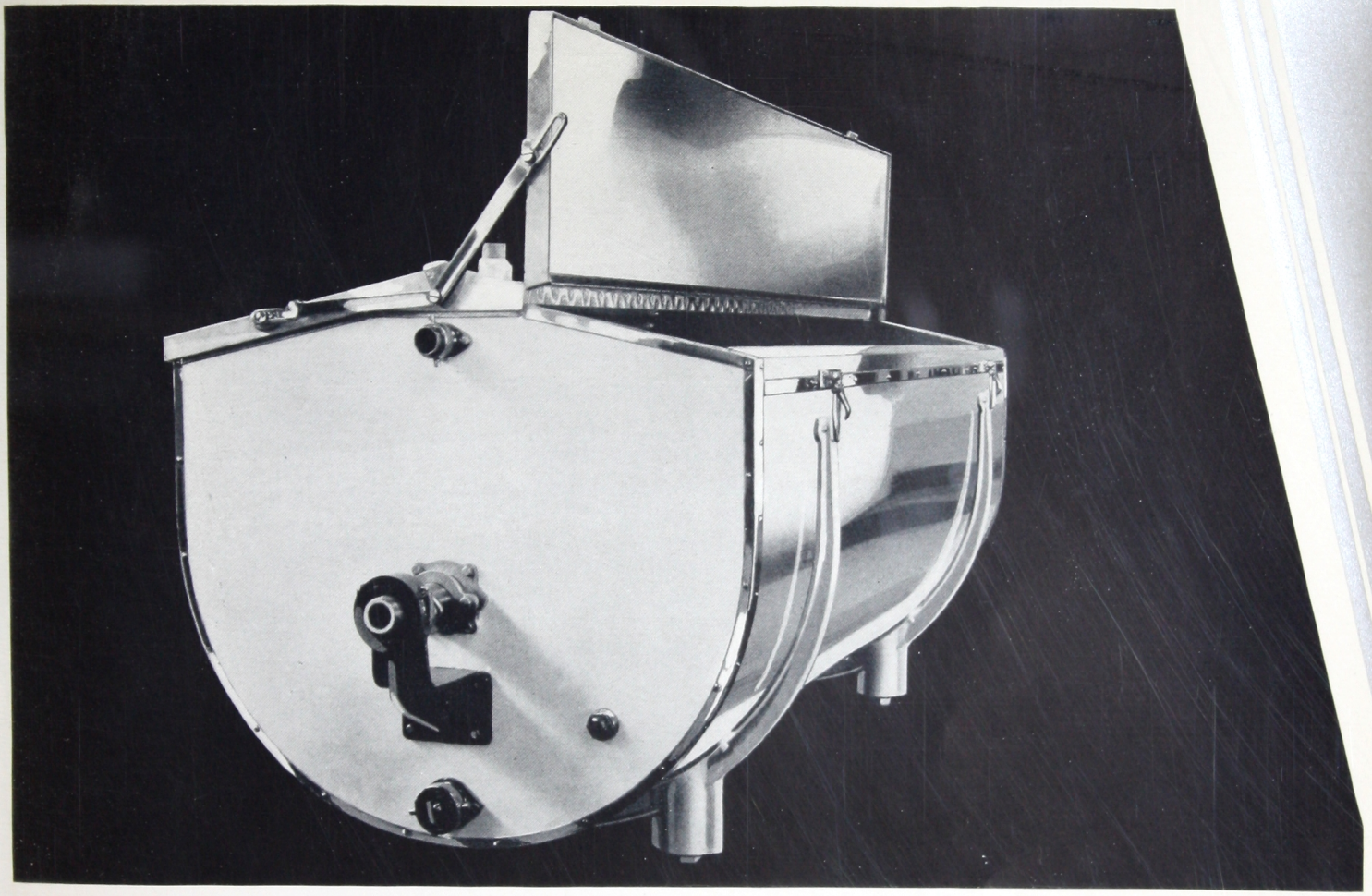
General views of Beacon Refinery where KA2 tubes are used

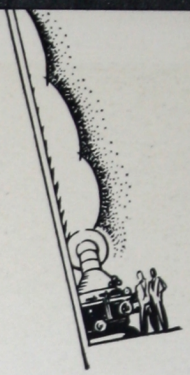
A DESCRIPTION of the almost countless additional applications for Enduro KA2 is impossible within the scope of this book. The calorimeter bombs at the right give but a hint of its possibilities for all kinds of scientific instruments. Below are wire wheel spokes of KA2 which suggest entirely new ideas in motor car style and design. Sporting goods of every sort will look better, function better and last longer when made of this durable material. Those who have used stainless golf irons will have some conception of its possible development. ¶ The shipping industry will find in KA2 the answer to corrosion problems which have been present in varying degrees for generations. The remarkable resistance of Enduro KA2 to the destructive "salt spray test" heralds its wide adoption for ship fittings of every sort from the engine room to the bridge. Aviation will welcome this weatherproof material. ¶ Experiments now being conducted on several leading railroads indicate that the strength and heat resistance of Enduro KA2 will greatly reduce costly over-haulings and idle time of expensive locomotive equipment. Exposed parts of automatic switch and signalling systems also will benefit from its immunity to atmospheric attack, while its use in passenger and dining cars is an imminent development.



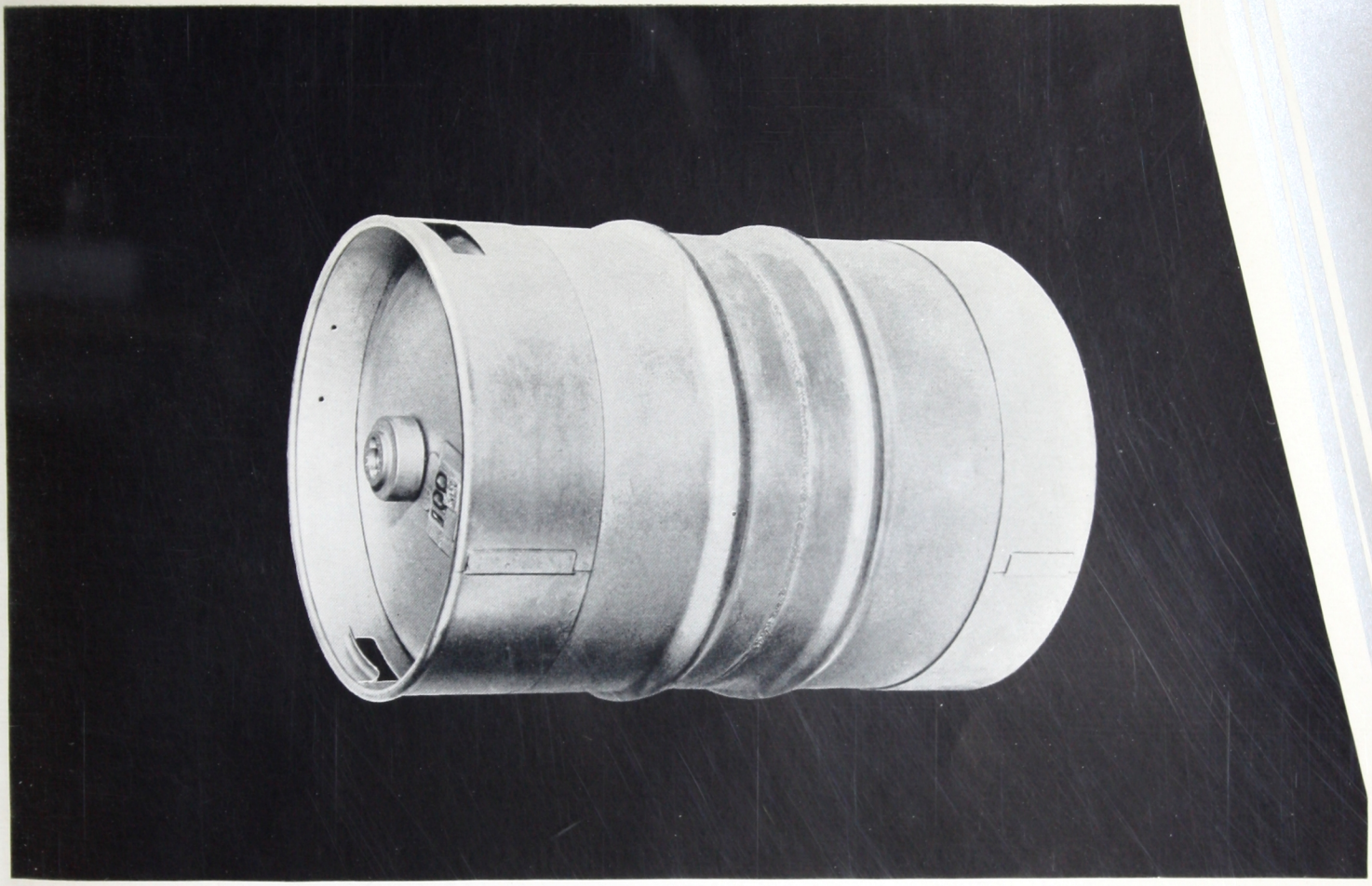


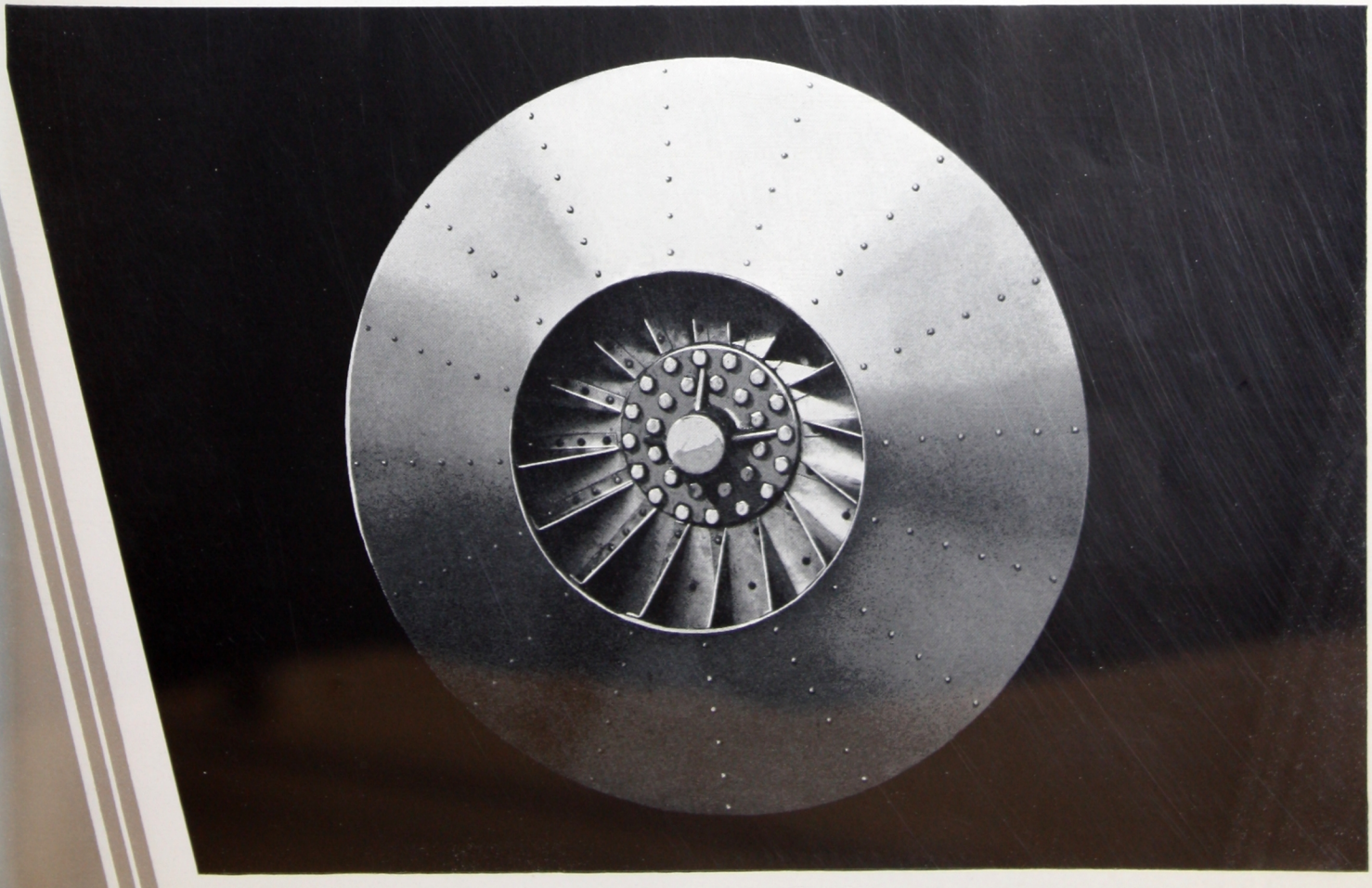
AGAIN in the dairy industry, the special properties of Enduro KA2 are so eminently fitted to the existing problems that it might have been developed for this purpose alone. Enduro is more resistant to milk, sour milk and cheese than pure nickel or other alloys of nickel. It will not contaminate dairy products under any conditions, yet it is less expensive than the materials commonly used in dairy machinery. ¶ Its shining surface is kept clean with greatest ease. There is nothing to wear off. At the right is shown a 100-gallon pasteurizer lined throughout with Enduro KA2. Below are cans of KA2 as used for the transportation of milk. ¶ Seamless tubing of Enduro KA2 is ideal for cooling coils and piping. Its availability in all standard forms makes it a logical and economical replacement for nickel, nickel-alloys, tinned copper or glass-coated metal for dairy-equipment. ¶ Ice cream plants will find wide use for Enduro KA2 in both manufacturing and marketing equipment. It is already being used with complete success in cheese vats and butter-making machinery. Wherever milk and milk products are handled, from the small dairy farmer with milking machine and cream separator, to the largest metropolitan plants, Enduro KA2 will give better results and actually save in initial cost as well as cost per year.





THE TRANSPORTATION and storage of corrosive materials always has involved handling problems of a serious nature. Many of these can be solved by the use of Enduro KA2. Shipping drums for nitric acid, as shown at the right, overcome the difficulties attending the use of highly fragile glass carboys. Their greater strength and safety are obvious. ¶ Before the advent of Enduro KA2, it was extremely difficult to produce drums that could be depended upon to meet specifications of the Bureau of Explosives and the Interstate Commerce Commission. The greater toughness and ductility of KA2 welds now permit the construction of drums which have passed all varieties of the drop test which could be devised. Tank cars for many materials as well as shipping containers for fruit juices will establish new standards of service when built of Enduro KA2. ¶ The disposal of acid fumes also is a problem in many industries. Blowers, ducts and fans of Enduro KA2 provide a complete solution. At the right is a blower wheel built entirely of Enduro. The hub is an Enduro forging. ¶ Wherever corrosive fumes of any description cause early failure of ordinary metals, a test installation of Enduro KA2 is advised. Such a test will demonstrate conclusively the advance that this material has made in the field of corrosion-resisting alloys.





# CHEMICAL AND PHYSICAL PROPERTIES

## TYPICAL ANALYSIS

| | |
|---|---|
| Carbon | under .15 % |
| Manganese | under .50 % |
| Phosphorus | under .025% |
| Sulphur | under .025% |
| Silicon | under .75 % |
| Chromium | 16.5-19.5 % |
| Nickel | 7.0-10.0 % |

**Weight**—Virtually the same as steel (Specific Gravity—7.86)

**Scaling Point**—Maximum temperature for continuous service—1700° F. (927° C.)

**Co-efficient of Linear Expansion**—.000016 per deg. C 0-100° C.

**Co-efficient of Linear Expansion**—.000018 per deg. C 0-600° C.

**Co-efficient of Linear Expans on**—.000020 per deg. C 0-1000° C.

**Specific Heat**—0.116

**Thermal Conductivity**—About 36% that of pure iron.

**Electrical Resistance**—In one meter length per square millimeter area:

| | |
|---|---|
| 68 F. ( 20° C.) | .73 ohms. |
| 212 F. (100° C.) | .90 ohms. |
| 932 F. (500° C.) | 1.06 ohms. |
| 1472 F. (800° C.) | 1.18 ohms. |

## TYPICAL PHYSICAL PROPERTIES

ENDURO KA2, being austenitic, cannot be heat-treated to produce desired physical properties, as can plain carbon steels. The sole means of altering physical properties is by cold working which hardens the metal materially. By careful control of such operations, a wide range of physical properties and hardness is obtained.

### ROUND BAR, HEAT-TREATED (ANNEALED) 2150° F. WATER QUENCH

**Room Temperatures**

| | |
|---|---|
| Tensile Strength | 85—95,000 lbs. per sq. in. |
| Yield Point | 30—40,000 lbs. per sq. in. |
| Elongation in 2 in. | 57—60% |
| Reduction of area | 70—75% |
| Rockwell "B" | 75—79 |
| Brinell | 130—145 |
| Charpy (impact) | 100—110 foot pounds. |
| Izod (impact) | 115—120 foot pounds. |

### SHEET, HEAT-TREATED (ANNEALED) 2150° F. AIR COOL

**Room Temperatures**

**No. 20 Gauge Sheet (.0375")**

| | |
|---|---|
| Tensile Strength | 85—90,000 lbs. per sq. in. |
| Yield Point | 33—38,000 lbs. per sq. in. |
| Elongation in 8 in. | 55—60% |
| Rockwell "B" | 68—72 |
| Erickson Cup Test | .475—.525 |

**No. 24 Gauge Sheet (.025")**

| | |
|---|---|
| Tensile Strength | 83—88,000 lbs. per sq. in. |
| Yield Point | 30—35,000 lbs. per sq. in. |
| Elongation in 8 in. | 52—57% |
| Rockwell "B" | 68—72 |
| Erickson Cup Test | .450—.500 |

## TENSILE PROPERTIES—HEAT TREATED (ANNEALED)

Specimens for hot tensile tests held 30 minutes at heat before pulling.
Distance between gauge marks equal to 10 times the diameter of the test specimen.

| Temperature (Degrees F.) | Tensile Strength (lbs. per sq. in.) | Yield Point (lbs. per sq. in.) | Elongation—% (1—10 dia.) | Reduction in Area—% |
|---|---|---|---|---|
| 68 | 105,000 | 49,000 | 55 | 62 |
| 392 | 101,000 | 45,000 | 53 | 66 |
| 572 | 98,000 | 40,000 | 50 | 65 |
| 752 | 91,000 | 35,000 | 45 | 62 |
| 932 | 83,000 | 28,000 | 39 | 61 |
| 1112 | 70,000 | 22,000 | 30 | . . |
| 1292 | 55,000 | 16,000 | 23 | . . |
| 1472 | 30,000 | 11,000 | 18 | . . |
| 1652 | 13,000 | 5,500 | 24 | . . |
| 1832 | 9,000 | 4,500 | 47 | . . |

# PHYSICAL PROPERTIES AT HIGH TEMPERATURES

IN selecting a material for the design of equipment which is to be used under high temperature conditions, where high stresses may be encountered, as in oil refinery operations, the following qualifications are necessary:

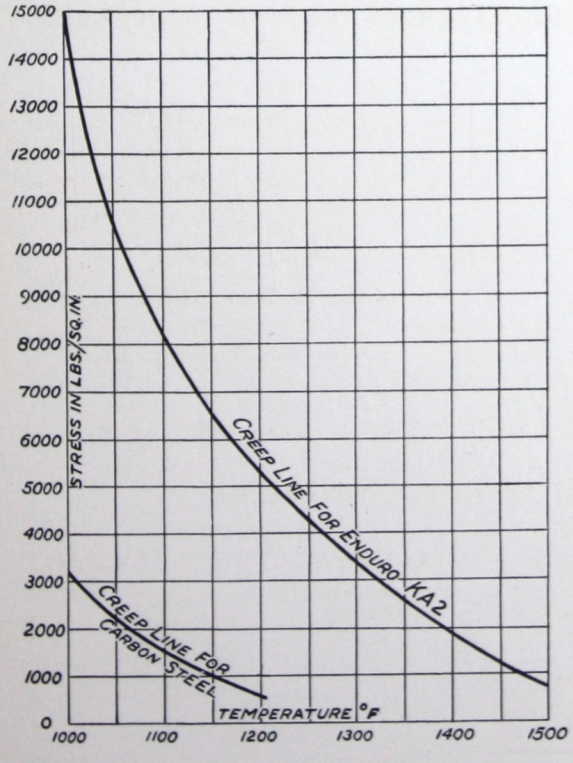
(a) **The metal must have the requisite strength at the specified temperature.**

(b) **It must not oxidize under the action of the flame or hot gases.**

(c) **It must not become brittle while hot or after cooling down from long exposures to high temperatures.**

(d) **It must resist the corrosive action of the materials with which it is in contact, such as liquids, gases, etc., in course of processing.**

## "Creep Strength" of Enduro KA2 Compared to Mild Steel




**These curves are the result of tests made by Professor F. H. Norton at Massachusetts Institute of Technology for The Babcock & Wilcox Tube Co.**

The tensile strength of metals, as ordinarily determined at room temperatures does not vary greatly with the rate at which the load is applied. But when the test is made at high temperatures, the rate of pulling of the tensile test piece has a marked effect on the ultimate tensile strength obtained. The more slowly the test piece is pulled, the lower is the strength shown by it. It is thus apparent that the tensile strengths of metals at high temperatures as ordinarily determined by short-time tests cannot be used for design purposes. It is equally evident that the effect of long time must be known before it is possible intelligently to design equipment to be used under such conditions.

If the strength of a metal at a given high temperature is determined only by ordinary tensile tests, a piece of equipment subjected to that temperature for a longer time, under pressure, using a safe fiber stress as determined by the short-time tests, will progressively stretch, or "creep." This will continue until a point is reached where the metal thickness becomes so greatly reduced that the pressure can no longer be withstood, and the apparatus will fail.

It is well to note that this reduction in the thickness of the metal may also be hastened by the effects of corrosion, or of oxidation, or a combination of both.

In order to design apparatus or equipment suitable for service at various elevated temperatures, when stresses will be high, it is necessary to determine the "creep strength" of the metal. The "creep strength" at a given temperature may therefore be defined as the stress at which the metal will elongate 1% during 100,000 hours at that temperature.

The "creep strength" of Enduro KA2, because of the high chromium content, together with the nickel, is notably higher than for plain carbon steel and is given in comparison in the accompanying chart. In applying this data to problems of practical design, stresses should be used corresponding to the highest temperatures anticipated, or a factor of safety introduced to prevent safe stresses being exceeded, should the temperature accidentally be increased.

# CORROSION RESISTANCE

Heat Treated (Annealed)

## Dilute Solutions

(The values give the loss in weight in grams per square meter after exposure for 100 hours at 20° C. (68° F.).

| | Common Steel | KA2 |
|---|---|---|
| .5% Magnesium Chloride solution | 5.44 | .00 |
| 1/10 normal Acetic Acid | 29.6 | .00 |
| 1/10 normal Hydrochloric Acid | 191.00 | .15 |
| 1/10 normal Nitric Acid | 147.50 | .00 |
| 1/10 normal Sulphuric Acid | 191.00 | .05 |
| 1/10 normal Tannic Acid | 38.0 | .00 |
| 1/10 normal Tartaric Acid | 54.8 | .00 |
| Pure water $CO_2$ | 28.03 | .03 |
| 2.5% Sodium Chloride (Salt) solution | 5.00 | .00 |
| 1.5% Sulphurous Acid | 491.00 | .00 |
| Well water | 1.00 | .00 |

## Air—Water—Gases

(As compared with common steel taken as 100)

| | KA2 | Common Steel |
|---|---|---|
| Air | .0 | 100 |
| Air, heavy with smoke | .86 | 100 |
| Air stream 700° C. (1292° F.) | .5 | 100 |
| Air stream 820° C. (1508° F.) | 1.5 | 100 |
| Mixture of steam, air and sulphurous acid at 400° C. (752° F.) | 2.5 | 100 |
| Mixture of steam, air and hydrochloric acid at 400° C. (752° F.) | 9.5 | 100 |
| Mixture of steam, air and ammonia at 400° C. (742° F.) | .72 | 100 |
| Seawater | .6 | 100 |
| Superheated steam and air at 400° C. (752° F.) | 5.9 | 100 |
| Well water | .0 | 100 |

## Chemical Attack

| | Temperature degrees C. | Loss in grams per hour per square meter |
|---|---|---|
| Acetic Acid 1:1 | Boiling | .03 |
| Acetic Acid concentrated | Boiling | .60 |
| Boric Acid concentrated | 100 | .00 |
| Butyric Acid | 20 | .00 |
| Butyric Acid saturated solution | 130 | .00 |
| Formic Acid 1:10 | Boiling | 2.48 |
| Formic Acid 1:1 | Boiling | 9.30 |
| .05% Hydrochloric Acid | Boiling | 1.79 |
| Lactic Acid | 20 | .00 |
| Nitric Acid 1:1 | Boiling | .04 |
| Nitric Acid concentrated | Boiling | .02 |
| Nitric Acid 1:10 | 20 | .00 |
| Nitric Acid concentrated | 20 | .00 |
| Nitric Acid plus 5% sulphuric acid | Boiling | .59 |
| Oleic Acid | 150 | .03 |
| Oxalic Acid concentrated | 20 | .00 |
| Oxalic Acid concentrated | 40 | .01 |
| Oxalic Acid concentrated | Boiling | 16.5 |
| Phosphoric Acid 10% | Boiling | .01 |
| Phosphoric Acid 45% | Boiling | .04 |
| Phosphoric Acid 80% | 110 | 31.30 |
| Phosphoric Acid 80% | 115 | 134.30 |
| Sulphuric Acid 10% | 20 | .07 |
| Sulphuric Acid 30% | 20 | .16 |
| Sulphuric Acid 66% | 20 | .001 |
| Sulphuric Acid 98% | 20 | .012 |
| Sulphuric Acid 20% | Boiling | 136.00 |
| Sulphuric Acid 98% | 100 | 4.68 |
| 10% Sulphuric Acid saturated with copper sulphate | 20 | .00 |
| 58% Sulphuric Acid, 40% Nitric Acid plus 2% water | 20 | .00 |
| 58% Sulphuric Acid, 40% Nitric Acid plus 2% water | 60 | .05 |
| 58% Sulphuric Acid, 40% Nitric Acid plus 2% water | 100 | .7 |
| 58% Sulphuric Acid, 40% Nitric Acid plus 2% water | 110 | 7.6 |
| Sulphurous Acid at a pressure of 20 atmospheres | 180 | 110.00 |
| Sulphurous Acid plus 1% Sulphuric Acid | 10 | .05 |

| | Temperature degrees C. | Loss in grams per hour per square meter |
|---|---|---|
| Ammoniacal Water | Boiling | .00 |
| Ammonium Chloride | Boiling | .00 |
| Ammonium Nitrate | 107 | .02 |
| Calcium Chloride | 100 | .00 |
| Carbolic Acid, crude | 90 | .05 |
| Chlorine, Iodine and Bromine and their Halogen acids | | dissolve |
| Citric Acid 5% | Boiling | .00 |
| Citric Acid saturated at 100° C. | Boiling | 2.19 |
| Copper Chloride 1:1 | Boiling | 464.00 |
| Copper Nitrate 1:1 | Boiling | .00 |
| Copper Sulphate 1:1 | Boiling | .00 |
| Gallic Acid saturated solution | Boiling | .00 |
| Iron Chloride 1:1 | 50 | 101.00 |
| Linseed oil plus 3% Sulphuric Acid | 200 | .05 |
| Mercuric Bi-chloride .7% | 20 | .88 |
| Mercuric Bi-chloride .7% | Boiling | 3.66 |
| Nitre | 20 | .52 |
| Potassium Bitartarate saturated | Boiling | .09 |
| Potassium Chlorate, saturated | Boiling | .00 |
| Potassium Hypochlorite | 20 | .01 |
| Potassium Hypochlorite | 105 | .53 |
| Potassium Hydroxide | 360 | 3.50 |
| Potassium Hydroxide | 600 | 37.90 |
| Potassium Hydroxide 27% solution | Boiling | .00 |
| Potassium Hydroxide 50% solution | Boiling | .40 |
| Sodium Chloride saturated | Boiling | .10 |
| Sodium Chloride 10% | Boiling | .00 |
| Sodium Chloride 25% | Boiling | .03 |
| Sodium Hydroxide 20% solution | 110 | .02 |
| Sodium Hydroxide 34% solution | 100 | .00 |
| Sodium Hydroxide | 318 | .22 |
| Sodium Sulphide 1:1 | 90 | .02 |
| Stannic Chloride | 20 | 2.28 |
| Stannous Chloride | 50 | .27 |
| Tartaric Acid saturated solution | Boiling | 7.8 |
| Zinc Chloride 78° Be. | 35 | .04 |

When exposed to the action of Hydrochloric Acid KA2 Steel shows insufficient resistance to corrosion.

# FABRICATION OF ENDURO KA2

**Forging.** Heat slowly to about 1500° F., then rapidly to 1900° F. —2200° F., which is the proper forging temperature. If forging is not completed when the piece has cooled to about 1700° F., it should be reheated, as the metal will be cold worked if forged below this temperature. Enduro KA2, having greater strength and hardness at high temperatures, will of necessity be somewhat stiffer than other metals and will require more blows under the hammer to accomplish the same reduction.

**Annealing.** To secure the best service from Enduro KA2, it is essential that it should be used in the heat-treated (annealed) condition. The metal then has greatest resistance to corrosion and oxidation, and is also most ductile, and hence best suited for bending, forming, deep drawing, etc. For this reason all Enduro KA2 is given the special processing necessary during the course of manufacture. To produce this condition Enduro KA2 must be heated rapidly to a high temperature (1950° F.-2100° F.) and cooled rapidly. In contrast to ordinary iron and steel, Enduro KA2 **must be cooled quickly** from the annealing temperature, either by quenching in water, if sections are large, or in air, if small. If in drawing or forming operations the metal becomes hardened because of cold working, and further softening is necessary for subsequent drawing, the above treatment should be used rather than the anneal with slow cooling as is customary with plain carbon steel.

**Removal of Scale.** To remove scale, pickle in a bath of 50% hydrochloric acid at a temperature between 160° F. and 200° F. Where such acid is not available a solution containing about 10% of sulphuric acid and 6-12% of rock salt (by weight) should be used hot. The effect of the rock salt is to liberate hydrochloric acid and results in a considerable saving of time compared with a straight sulphuric acid pickle. After pickling rinse thoroughly and dip in a hot solution of nitric acid 10-20% strength and wash in hot water.

**Riveting.** Enduro KA2 is the ideal material for rivets. As it does not harden on rapid cooling, nor develop coarse crystalline structure on heating, the accurate temperature control required for straight chromium-iron rivets is not necessary. Rivets may be driven at high temperatures (2100° F.) or cold, with equal success, the rivet remaining tough and thoroughly dependable. There is therefore less uncertainty in driving rivets of Enduro KA2 than there is with common steel.

**Welding.** Enduro KA2 may be welded by either the acetylene torch or electric arc, using specially prepared welding rods. It may also be spot and resistance-welded, but cannot be forge or hammer-welded. Having no capacity for hardening, welds remain tough and ductile and do not develop coarse, crystalline structure characteristic of the straight chromium-iron alloys. (See special circular with instructions for Enduro welding.)

For acetylene welding, uncoated welding rods should be used. With plates and other heavy materials, chamfer the edges to be welded and place these a small distance apart. Build up a bead between these edges, keeping the flame pointed in the direction of welding so as to preheat the work. Use a slightly reducing flame, and see that it is no larger than necessary for the work to be done.

For electric arc welding, special coated rods must be used. Reverse polarity (electrode must be positive and work the negative pole) and regulate the machine to give the same or lower voltage than would be used with plain steel rods, and to give moderately high current. Definite instructions cannot be given as much will depend upon the character of the work and the type of machine used.

While welds made with Enduro KA2 are naturally tough and ductile, the annealing treatment given above is recommended if the welded material is to withstand severe corrosive attack. This treatment will tend to produce homogeneity in the metal, and to remove the difference in structure between the weld and the adjacent metal, which is the primary cause of local attack in welded structures. Numerous analyses show that there is little change in the composition of the metal deposited in the weld.

**Soldering and Brazing.** Enduro KA2 may be soldered without difficulty, firm, strong joints being produced. For pickled finish sheets, the ordinary muriatic acid cut with zinc may be used. For polished sheets, if there is difficulty in making the solder adhere, the surface may be dulled with the following solution:

| | |
|---|---|
| Muriatic Acid ($HCl$) | 90 Parts |
| Ferric Chloride ($FeCl_3$) | 50 parts |
| Nitric Acid ($HNO_3$) | 3 parts |

The solution should be allowed to act for 5 to 10 minutes, or longer, if necessary, then wiped off. Tinning is then to be done in the usual way. If difficulty is still encountered, an acid solution similar to the above, but which has been cut with zinc, should be used. After soldering, **all traces of acid must be thoroughly removed** by washing, as the acid attacks the metal readily. On account of the low thermal conductivity, use a large soldering iron which will have sufficient heat capacity to heat the metal thoroughly.

For brazing, proceed in the usual manner, observing the precautions of having the metal thoroughly hot. If there is difficulty encountered in making a firm joint, the metal should be tinned by the process given above before brazing.

A satisfactory flux for brazing may be made by mixing 4 parts of borax with one part of ferric chloride by weight, in a solution of zinc chloride made by dissolving zinc in muriatic acid, to form a thick paste, and applying a small quantity of this to the parts to be brazed before heating. Then proceed with ordinary brazing material and fluxes. Owing to the ease with which Enduro KA2 may be welded, this method of making joints is to be preferred to brazing.

**Machining.** Being an austenitic alloy, Enduro KA2 is tough and somewhat difficult to machine. Best results are obtained with slow cutting speeds and moderately heavy cuts. Tools must be ground and kept sharp, and with a steep side and lip rake (at least 15 degrees). In threading, arrange so that four or five teeth engage, instead of the usual two or three.

**Grinding and Polishing.** Grinding should be done wet, if possible, care being observed that the metal does not become unduly heated. Always use a freshly dressed wheel so that there can be no contamination of the surface by other metal which may be present on the surface of the wheel.

As regards polishing, the character of the finish of the exposed surface is the most important factor in producing resistance to stain and tarnishing; hence, the more perfect the finish, the less the likelihood that the metal will discolor.

When polishing from the white pickled (No. 1) finish, commence with a No. 80 abrasive, using either alundum or Turkish emery. Follow this with No. 150 abrasive on a grease wheel. This should be followed with No. 180 abrasive on a grease wheel. To produce the highest finish, follow the No. 180 abrasive with stainless steel rouge (green chromic oxide). **Do not use the ordinary red jeweler's rouge.**

As with all polishing operations, the perfection of the finish depends upon the thoroughness with which the scratches from the previous operation are removed. In order best to accomplish this, it is advisable, where the work can be so manipulated, to make the direction of polishing in each operation at right angles to the direction of the previous operation; and to continue each operation until all marks and scratches from previous operations are removed.

## Enduro KA2 Shapes and Sizes

Enduro KA2 is furnished as follows:

**Rounds,** hot rolled, cold drawn, centerless ground and polished.

**Squares,** hot rolled and cold drawn.

**Hexagons,** hot rolled and cold drawn.

**Flats,** hot rolled and cold drawn.

**Sheets,** standard gauges and sizes, annealed and pickled, one side polished and both sides polished.

**Plates** in practically any size and thickness obtainable in plain steel; large size one-piece flanged and dished heads.

**Strip,** hot rolled.

**Forging blanks,** any reasonable weight or size.

**Shapes, angles, channels, I-beams, etc.** Sizes on application

**Tubing,** both seamless and butt-welded.

**Welding Rods,** $\frac{1}{8}$", $\frac{5}{32}$", $\frac{3}{16}$" diameter. Coated and uncoated carried in stock for electric and acetylene welding.

**Castings,** can be furnished of Enduro KA2 analysis by special arrangement.

**Bolts and nuts, rivets, screws, cold rolled strip, wire** and many other items can be obtained of Enduro KA2 from various sources. Names of manufacturers will be gladly furnished.

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